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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 821

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. June 4, 1920

FROST PROTECTION IN LEMON ORCHARDS

By

A. D. SHAMEL, Physiologist, L. B. SCOTT, Pomologist, and C. S. POMEROY, Assistant Pomologist, Office of Horticultural and Pomological Investigations

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CLIMATIC CONDITIONS IN THE CORONA DISTRICT.

ON DECEMBER 25 and 28, 1912, and during January 5, 6, 7, 8, 11, 12, 15, 22, and 23, 1913, many lemon trees in California were severely injured by low temperatures and the accompanying adverse atmospheric conditions, including violent winds and very low relative humidity. As the writers were then stationed in southern California in connection with the citrus-fruit improvement investigations of the United States Department of Agriculture and were spending considerable time in the lemon district near Corona, it seemed advisable to study the effect of these low temperatures in this particular region.

The maximum and minimum temperatures, the rainfall, and notes upon wind and other climatic conditions for December, 1912, and January and February, 1913, in the immediate region where these studies were made are shown in Table I. These data were gathered in accordance with the rules of the United States Weather Bureau, and the climatological instruments were housed in a shelter, as shown

[1] The writers are especially indebted to Miss Katharine G. Bonner, of the Office of Horticultural and Pomological Investigations, for the computations and the preparation of the tables in this bulletin.

in figure 1. On nights when minimum temperatures of 31° F. or lower were recorded, firing was practiced in all orchards that were provided with heaters.

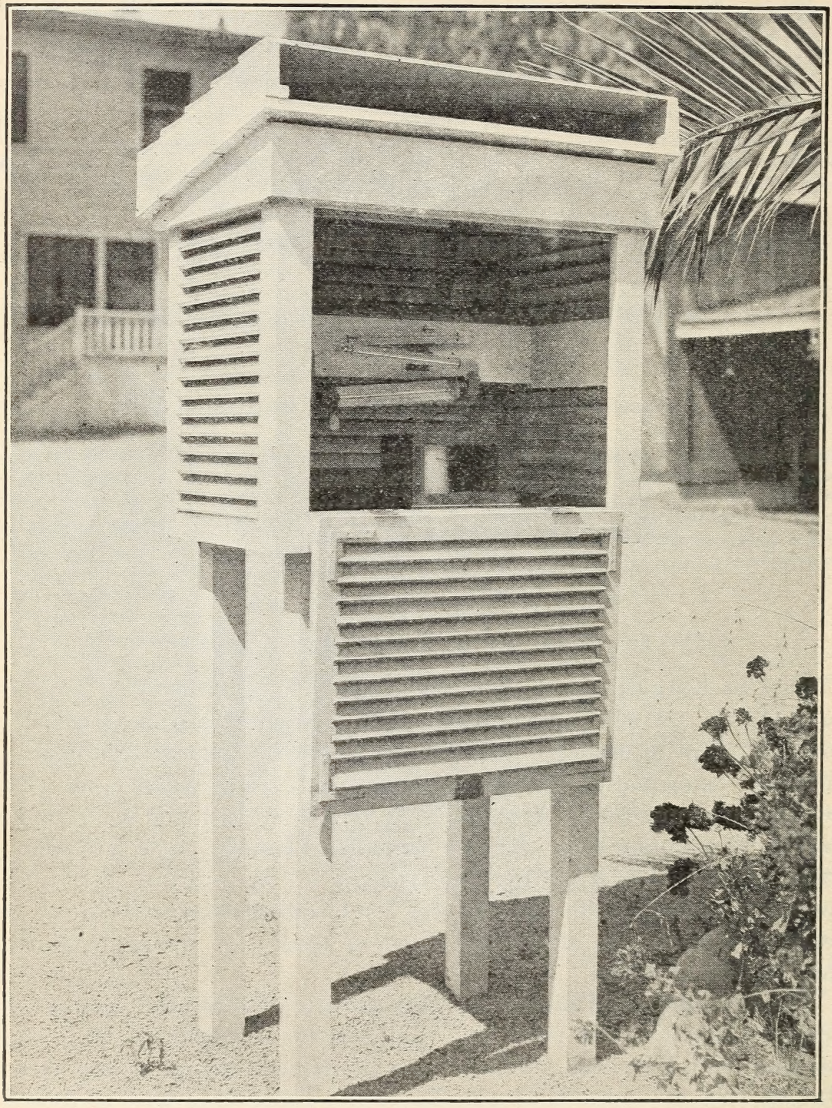


FIG. 1.—Thermometer shelter, showing the arrangement of the maximum and minimum thermometers and the thermograph from which the data presented in Table I were secured. The shelter faces the north, and the instruments are placed about 3 feet from the ground.

The Corona district consists of an area of about 5,000 acres of citrus fruit, in an almost unbroken planting, upon a mesa which slopes to the north and west. The orchards in which the studies discussed in this bulletin were made are located in the center of this area. The

altitude of that portion of the mesa where these studies were made is about 1,000 feet. The mesa is protected on the south and east by the Santa Ana Range of mountains, having a general altitude of about 4,000 feet. It faces the Santa Ana River valley to the north and west, and has an open and unobstructed exposure in these directions.

TABLE I.—*Climatological record of a lemon orchard near Corona, Calif., for the months of December, 1912, and January and February, 1913.*[1]

Day of the month.	December, 1912.				January, 1913.				February, 1913.			
	Temperatures (° F.).		Rainfall (inches).	Notes.	Temperatures (° F.).		Rainfall (inches).	Notes.	Temperatures (° F.).		Rainfall (inches).	Notes.
	Maximum.	Minimum.			Maximum.	Minimum.			Maximum.	Minimum.		
1	65	47			74	35			64	39		
2	60	43			79	47			66	41		
3	70	34			83	53			64	34		
4	67	34		[2]	59	32		[3]	64	34		
5	57	38		[3]	55	29		[3]	63	42	Trace.	
6	57	38		[3]	42	19		[4]	70	47	0.38	
7	59	33		[3]	52	25		[3]	60	50	.25	
8	65	41			59	25		[3]	59	47	.65	
9	[5]	36			48	32			69	42		
10	64	34			49	32			69	40		
11	66	32			54	29			64	39		
12	73	41			59	29			71	38		
13	72	39			68	32			78	36		
14	70	32			59	32			73	39		
15	66	38	0.05		58	31	0.88		80	46		
16	58	32			55	42	.33		76	41		
17	75	35			56	39	.14		72	42		
18	78	48			51	34			65	40		
19	75	44			58	40			57	36	.28	
20	68	45		[3]	[5]	[5]	Trace.		57	29		[6]
21	59	30		[3]	64	35			53	39	.32	
22	61	44		[3]	56	27			55	38	.50	
23	68	36			65	30			52	30	.15	
24	66	33			71	44			54	33	1.06	
25	62	31			77	44			54	45	.98	
26	63	42			78	39			54	35	.04	
27	69	41			76	40			58	37	.03	
28	67	31			78	43			63	32		
29	67	32			72	40						
30	66	33			73	38						
31	64	33			78	47						

[1] Records secured by Thos. C. Sias, weather observer for the Corona district.
[2] White frost.
[3] Violent north wind.
[4] Violent north wind; minimum temperature on road alongside orchard at 3 a. m., 17°; temperature did not reach 32° until 11 a. m.
[5] Missing.
[6] No damage, owing to clouds and high humidity.

METHOD OF ORCHARD HEATING.

Many of the lemon orchards in the Corona district were provided with orchard heaters for the protection of the trees and fruits during the low temperatures of December, 1912, and January, 1913. These heaters, for the most part, were oil burners of simple construction. The type of heater in most common use is shown in figure 2. The fuel used was a low grade of distillate. The heaters varied greatly in size, the smaller ones holding from 1 to 3 gallons of fuel each, while the larger ones each had a capacity of 7 to 9 gallons of oil. Some experimental heaters, having a much larger capacity and arranged

to provide a more complete combustion of fuel with a consequent small amount of smoke or smudge, were tried during this period, but they were abandoned later, owing to mechanical difficulties and other causes.

Usually one heater for every tree was provided, and in some cases two rows of heaters were arranged on the north and west sides of the orchards. The heaters were usually placed in the center of the square made by four trees, as shown in figure 3, so as to avoid as far as possible injuries to the foliage and fruits from the flames or from

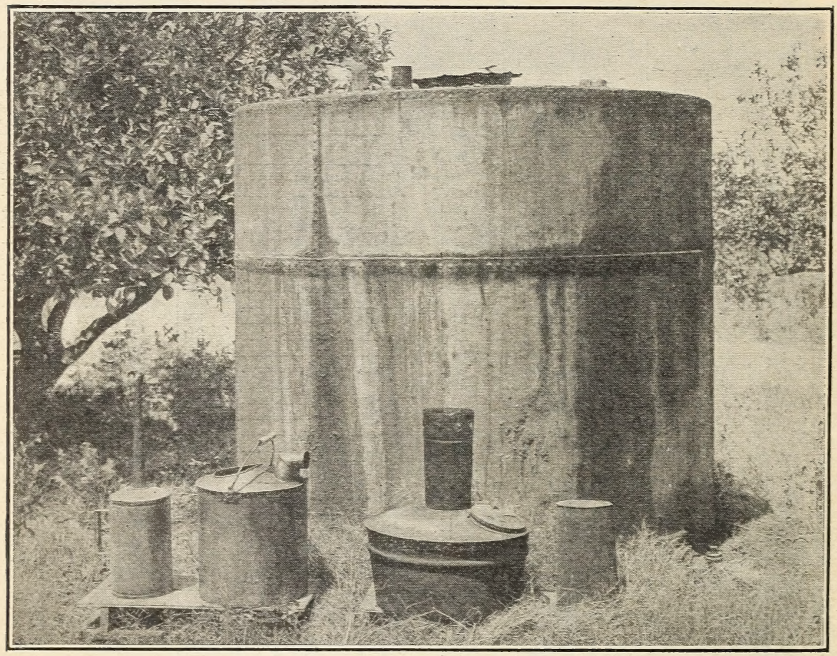


FIG. 2.—The type of heater in most common use in the Corona district. From left to right in the foreground are shown a gasoline torch for lighting the orchard heaters, a can for distributing oil to the heaters, and a style of heater of about 9 gallons' capacity. In the background stands a small oil tank. The oil is drawn off from the tank through a valve at its base, shown at the right.

close contact with the heaters. They were lighted, as a rule, when the temperature in the orchards dropped to 31° F., although the temperatures at which lighting began depended somewhat upon other conditions than those of temperature and the time of night at which the low temperature was reached. For example, if the temperature dropped to 32° F. before midnight the heaters were usually lighted at this temperature. If the temperature did not drop below freezing until the early morning, as was frequently the case, the heaters were usually lighted at 30° F. In some cases when the temperature did not drop too near the danger point until 5 to 6 a. m. the heaters were not lighted until the thermometer reached 29° or 28° F.

Adequate provision was made in all the protected orchards in which these studies were conducted for refilling the heaters from storage reservoirs, such as the one shown in figure 4, and for their continuous care during the frosts. One of the methods used for distributing the oil is shown in figure 5. It can be safely said that in the orchards under observation the maximum efficiency of the heaters was obtained during the cold periods.

OBJECTS OF THE INVESTIGATIONS.

The effect of the low temperatures upon the lemon trees in nonheated orchards was very noticeable immediately following the freeze. The trees in nonheated orchards were partially or completely defoliated, as shown in Plates I and II. The trees in heated orchards did not show this condition to any marked extent except in the upper branches, where the leaves were blown off by the violent winds which accompanied the low temperatures, as shown in Plate III. In the nonheated orchards in many instances the bark on the branches and, in some cases, on the trunk of the trees, was split more or less severely. Often it was necessary to cut off these injured branches during the spring months following the low temperatures, in order to aid the trees in recovering from frost injury. In nearly all cases where trees were defoliated it was found desirable to whitewash the trunks and main branches, in order to protect the trees from further injury by exposure to the sun. It was therefore possible, in a general way, to determine the amount of immediate injury to the trees themselves.

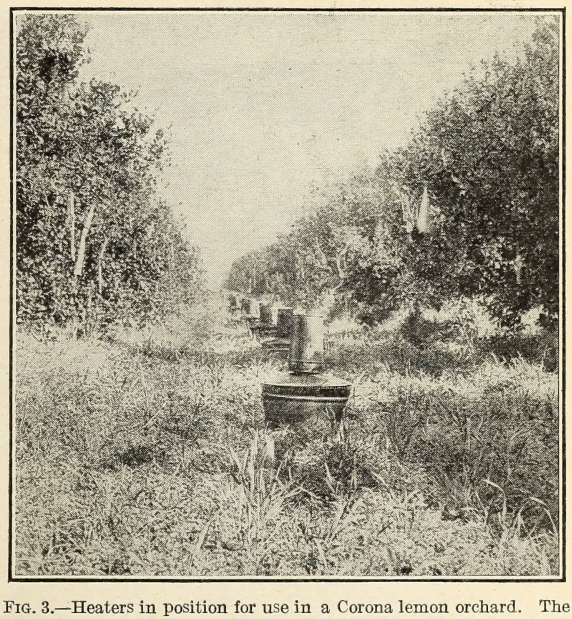


FIG. 3.—Heaters in position for use in a Corona lemon orchard. The heaters are usually set on a small board or other support in order to avoid as far as possible damage from rust due to contact with the soil. Great care must be used in order to prevent leakage from the heaters, as even small quantities of oil in orchard soils have been found to be injurious to the trees. As soon as the cold weather is over, the pots are usually removed from the orchard, emptied, cleaned, coated with hot oil, and stored for the summer.

A number of other factors are of even greater consideration than the immediate injury to the trees. In order to secure definite information concerning these factors, the investigations discussed in this bulletin were undertaken. The objects of these investigations were (1) the determination of the effectiveness of orchard heaters, as measured by the number, commercial quality, and value of the fruits produced by lemon trees in orchards protected by oil heaters and in comparative unprotected orchards, (2) the determination of the length of time it took trees in orchards which were not protected with heaters to return to normal production, (3) the determination of the behavior of lemon trees in heated and nonheated orchards the

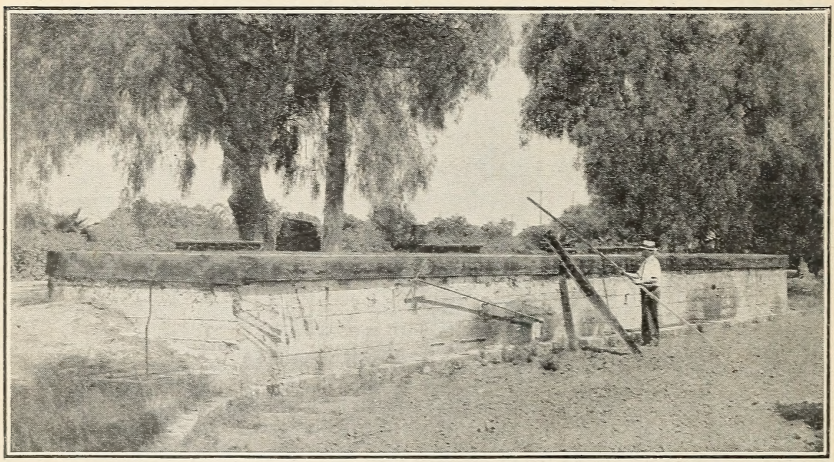


FIG. 4.—Cement reservoir for the storage of oil used in orchard heaters. A large supply of oil is stored in this tank to be used for refilling heaters during periods of low temperature. The reservoir is arranged so that the oil can be carried by gravity through pipe lines to various sections of the orchard, or the oil can be pumped, if necessary, directly into tank wagons for distribution to the heaters.

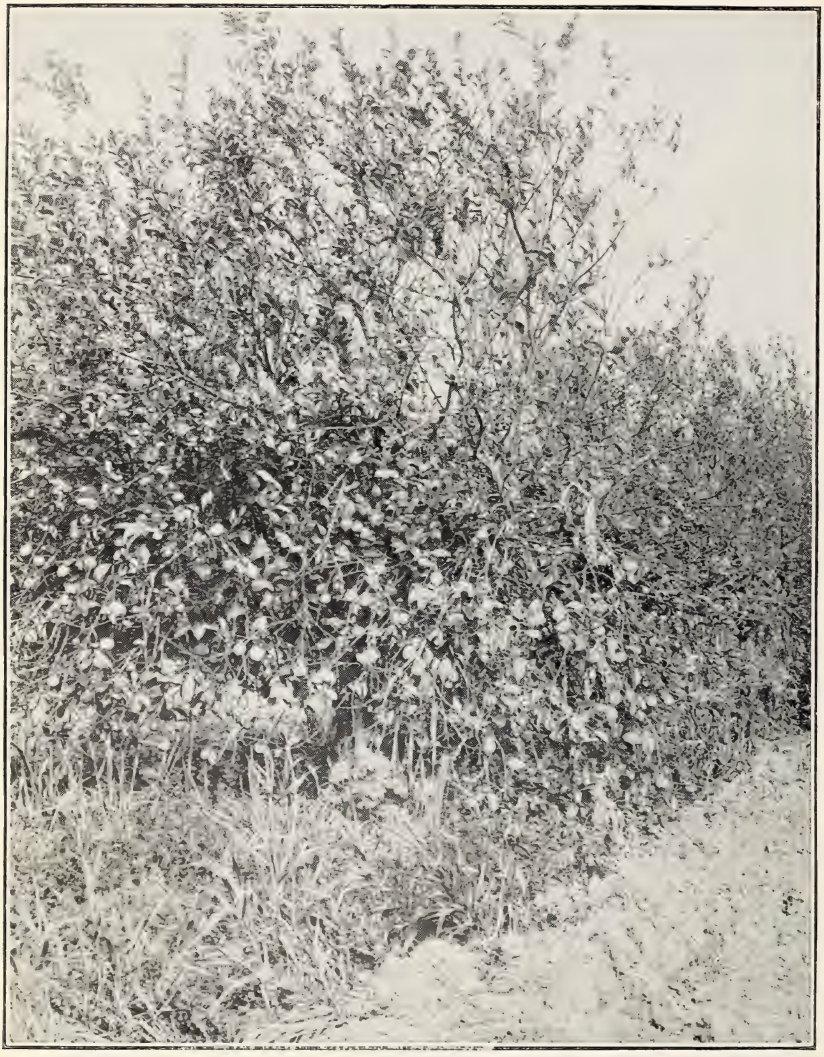
second year after the freeze, and (4) a comparison of the frost injury in orchards of both Eureka and Lisbon lemon trees, which are the two important varieties grown in California.

On account of the fact that previous to the freeze no tree records had been kept in the comparative heated and nonheated orchards under observation it is not possible to show the behavior of the trees in these orchards prior to 1913. However, all plats were located in orchards where the conditions were as nearly comparable as possible.

The object of this publication is not to cover the subject of frost protection, but to submit data which shows the actual behavior of trees in protected and unprotected lemon orchards in one district of southern California for the two years following the freeze of January, 1913.

A EUREKA LEMON TREE TYPICAL OF NONHEATED ORCHARDS.

This tree shows excessive defoliation caused by the low temperatures and strong winds during the winter of 1912–13. A comparison with Plate II shows the relatively greater injury done to Eureka than to Lisbon trees in the unprotected orchards. Photographed in January, 1913.



A LISBON LEMON TREE IN PLAT 10, TYPICAL OF NONHEATED ORCHARDS.

Most of the fruits which were not protected by heaters during the low temperatures of 1912–13 were so badly frozen as to render them unmarketable, and the trees were almost defoliated by the low temperatures. Many of the unprotected trees were seriously injured by the splitting of the bark, so that it was found necessary to practice severe pruning in order to cut off the injured limbs and renew the tops. Photographed in January, 1913.

A LISBON LEMON TREE IN PLAT 9, TYPICAL OF PROTECTED ORCHARDS.

While the top of this tree, which was protected by orchard heaters, was partially defoliated by the violent winds, the tree and its fruits were but slightly injured by the low temperatures of 1912–13. Photographed in January, 1913.

PLAN OF THE INVESTIGATIONS.

The investigations discussed in this bulletin were one feature of a general study of the effect of frost injury on citrus fruits conducted by Dr. H. J. Webber, Director of the Citrus Experiment Station of the University of California, at Riverside, his associates, and the writers. A report on certain phases of the studies has been published by Webber and others.[1] Only a brief abstract of the investigations discussed in the following pages appears in the above-mentioned report.

Owing to the fact that frost injuries frequently vary in degree in the same orchard, due to such local conditions as the lay of the land, care was used in the selection of the comparative heated and non-heated plats, so that they were practically identical with respect to

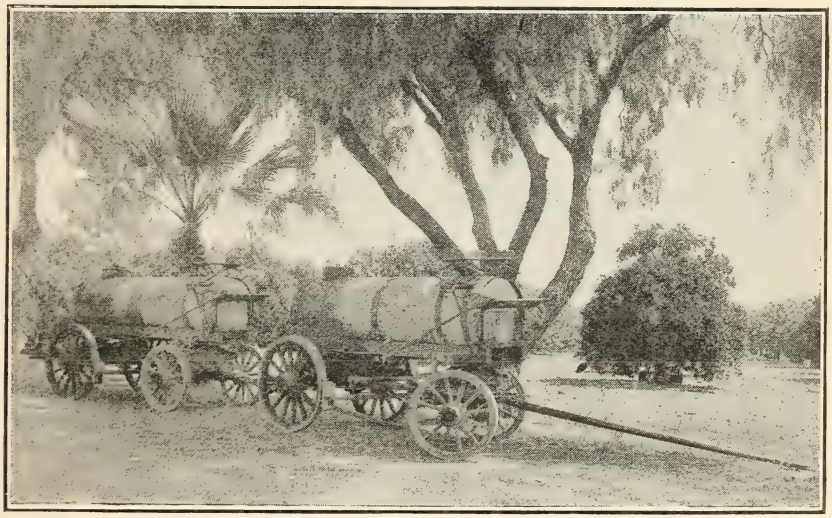


FIG. 5.—Tank wagons used for distributing oil to empty heaters. These provide means for quickly filling the empty heaters during periods of continued low temperature. Some of the orchards are fitted with pipe lines which distribute the oil to different sections.

the influence of low temperatures and other climatic conditions. A committee, which included Dr. Webber, four prominent citrus growers, and the writers, made the selection of the plats and agreed upon their adaptability for the purpose of this study. In every case the comparative orchards were very near together, usually adjoining groves, and at the same altitude. The trees were about the same age—20 years—so that differences in production could not be attributed to any marked difference in the age of the trees. After a careful survey of the orchards the trees for the comparative plats were selected with a view to insuring fair and comparative conditions.

[1] Webber, H. J., and others. A study of the effects of freezes on Citrus in California. Cal. Agr. Exp. Sta. Bul. 304, p. 243-321, 22 fig. 1919.

In order to enable the observers to secure individual-tree performance records from as many as 10 plats it was found necessary to arrange the plats in such order that the smallest possible number of trees would give reliable data of the comparative tree and fruit conditions in the heated and nonheated orchards. Each plat included a block 10 trees long by 10 trees wide, or, roughly speaking, an acre of lemon trees. On account of the great amount of work which would be necessary in securing individual-tree performance records from all the trees in the selected plats, it was found necessary to restrict the actual detailed records to not more than 10 trees, and in some cases to 5 trees, in each plat. The trees finally used for this study were located by taking one of the trees at the center of the block and the four trees at the corners. It was thought that by securing the records of these trees and then by multiplying the figures obtained by the factor 20 a fairly accurate line could be obtained on the production of the plat on an acre basis. Where 10 trees were used in securing the records two trees were taken in the center of the block and two on each corner. In these plats the acre figures were secured by multiplying the total production of the 10 trees by the factor 10.

After the performance-record trees were located they were carefully studied from the standpoint of strain characteristics, as it was desirable that only typical trees of the best strain of the Lisbon and Eureka varieties should be used for this study.

TABLE II.—*Description of the plats selected for the study of the effectiveness of orchard heaters for frost protection.*

Plat.	Variety.	Treatment.	Number of trees.	Number of pickings.	Picking period.	Comparative plats.
No. 1	Lisbon	Not heated	5	8	Feb. 14 to Dec. 12, 1913	4
No. 2	do	(1)	5	6	Feb. 15 to Nov. 17, 1913	3
No. 3	Eureka	(1)	10	6	do	2, 5, and 7
No. 4	Lisbon	Heated	5	8	Mar. 3 to Dec. 12, 1913	1
No. 5	Eureka	(2)	10	8	Mar. 4 to Dec. 12, 1913	3 and 7
No. 6	Lisbon	Heated	10	19	Mar. 6 to Dec. 8, 1913 Jan. 3 to Dec. 23, 1914	8
No. 7	Eureka	do	10	8	Mar. 7 to Dec. 13, 1913	3 and 5
No. 8	Lisbon	Not heated	10	11	Mar. 10 to Dec. 18, 1913 Jan. 31 to Dec. 30, 1914	6
No. 9	do	Heated	10	8	Mar. 12 to Dec. 12, 1913	10
No. 10	do	Not heated	10	3	Mar. 14 to Dec. 1, 1913	9

[1] Plats 2 and 3 were partially protected by heaters in neighboring orchards.
[2] Inadequately heated; one heater for every four trees.

The position of the plat was adjusted so that the trees finally used were, with one exception, of the same strain in all the comparative plats. The number of the plat, the variety of lemons, a statement of whether the orchards were heated or nonheated, the number of trees in each plat, the number of pickings made from the trees, the periods during which the pickings were made, and the number of plats used for comparison are shown in Table II. A study of this

table shows that plats 1, 2, 8, and 10 were located in nonheated Lisbon orchards, while plats 4, 6, and 9 were in heated orchards. Plat 3 was located in a nonheated Eureka orchard, and plats 5 and 7 in heated Eureka orchards. Plats 2 and 3, which are listed as nonheated, were partially protected by heaters in neighboring orchards. Plat 5, which is listed as a heated plat, was inadequately supplied with orchard heaters, as there was only one heater for every four trees. This plat was included for the purpose of comparing inadequate orchard heating with no heating and with adequate heating.

METHOD OF SECURING RECORDS.

The fruit from each individual tree at each picking was assorted into four grades, namely, Green, Tree-Ripe, Frozen, and Cull. The Green grade included all fruits which had either a dark-green or light-green color, and which, from outward appearances, were apparently sound. These fruits were expected after curing to constitute a first grade of valuable commercial lemons. The Tree-Ripe grade included the apparently sound fruits which had a yellow color. These fruits were usually considered to be of some commercial value. It was not necessary to cure them before shipping to the markets. The Frozen grade included all fruits which were seriously injured by the low temperature, as shown by their soft or partially dried-up condition. When there was any question or doubt as to whether the fruit was frozen or not it was cut open, so as to make an accurate determination before classifying. The Cull fruits were those which for some reason aside from frost injuries were unfit for the market. A frequent cause of Culls was decay of various kinds induced by mechanical injury to the fruits. Many of these injuries were brought about by punctures or bruises during the violent winds that accompanied the cold weather in January, 1913.

After the assortment of the fruits from each tree the number and weight of the lemons of each grade were determined and recorded in special field-note forms, as shown in Table III.

As lemons are usually picked to a certain uniform size with the aid of metal picking rings, no attempt was made to size the fruits, as would have been necessary with oranges or grapefruit. If desired, an idea of the relative size of the lemons can be secured by comparing the number with the weights of the fruits.

Inasmuch as the frozen lemons began to dry out soon after the freeze, thus altering their normal weights, the data regarding the comparative sizes of the fruits secured in this way are likely to be somewhat unreliable. For this reason, also, in studying the effect of the freeze upon the production of the trees in the different plats, it seems desirable that most of the conclusions should be based upon the number instead of the weights of the fruits.

TABLE III.—*Field record form used in making individual-tree records in the orchard.*

[This blank provides space for recording data from four trees at one picking. The fruits were sorted into the following grades: Green, Tree-Ripe, Frozen, and Cull, and the number and weight of the fruits in each grade are recorded. The record thus made in the orchard was afterwards transferred to a yearly series form, as shown in Table IV.]

Grove, *Corona Lemon Co.* Date, *Mar. 6, 1913.* Plat, *1.* Variety, *Lisbon.*

Tree.[1]	Green grade.		Tree-Ripe grade.		Frozen grade.		Cull grade.		Total.	
	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.	Weight.	Number.
	Lbs. oz.		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*		*Lbs. oz.*	
1–26–17	197 1	684	60 6	291	11 14	64	0 0	0	269 5	1,039
1–26–9	41 14	144	1 10	6	2 11	19	0 0	0	46 3	169
1–26–8	130 12	455	33 9	158	9 9	50	0 0	0	173 14	663
1–32–8	64 4	219	3 4	15	8 14	47	0 0	0	76 6	281

[1] Each tree in the investigational plat was given an individual-tree number which included the block number, row number, and location of the tree in the row; thus tree 1–26–17 means that that particular tree is in block 1, row 26, and the 17th tree from the end of the row, always numbering from some fixed point.

The data secured for each tree at each monthly picking were transferred to a yearly series record form, as shown in Table IV. The number and weights of the Green, Tree-Ripe, and Frozen fruits for all the record trees in each plat were added at each picking and multiplied by 10 or 20, as determined by the number of record trees, to secure an approximate record of the plat on an acre basis.

TABLE IV.—*Yearly series record form, showing the method of recording data for each tree for an entire year.*

[The monthly records as shown in Table III are here transferred to the yearly form.]

Location, *Corona, Calif.* Variety, *Lisbon.* Grower, *Corona Lemon Co.* Date, *1913.* No. of tree, 1–26–17.

Classification.	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.	Total.
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	197 1	5 6	11 15	16 13	2 11	0 11	2 11	39 15	277 3
Tree-Ripe grade	60 6	1 11	1 8	3 3	3 2	0 5	1 3	1 10	73 0
Frozen grade	11 14	0 5	0 3	0 0	0 0	0 0	0 7	0 0	12 13
Cull grade	0 0	0 8	0 8	0 4	0 6	0 0	0 9	0 4	2 7
Total	269 5	7 14	14 2	20 4	6 3	1 0	4 14	41 13	365 7
Number of fruits:									
Green grade	684	21	45	65	10	3	11	150	989
Tree-Ripe grade	291	9	5	16	17	2	8	7	355
Frozen grade	64	6	1	0	0	0	3	0	74
Cull grade	0	4	2	2	3	0	4	2	17
Total	1,039	40	53	83	30	5	26	159	1,435

PRESENTATION OF DATA.

In the succeeding tables only the computed figures for the different plats, as shown on an acre basis, are given. It is thought that the presentation of the average number of sound and frozen fruits for each month in the year in all the plats, as expressed in acre terms, will give the reader a comprehensive idea of the behavior of the different orchards under observation. As will be noted in Table II, the first

pickings were not all made on the same day. This condition was due to the fact that each plat was of necessity picked in turn, and the careful examination of every fruit for possible frost injury required considerable time. The number of pickings for the plats is not the same in all cases, for the reason that in some of the nonheated plats the great proportion of the fruit on the trees at the time of the freeze was removed at the first picking in 1913, while in some of the heated plats as many as eight pickings were made during the year.

Table V shows the estimated production by grades for an acre of Lisbon lemon trees (plat 1) during February, April, May, June, August, September, October, and December, 1913. These figures are calculated from the actual individual-tree performance records of five selected trees in the plat. This orchard was nonheated during the winter of 1912–13 and was selected for comparison with plat 4, which is in a Lisbon lemon orchard that was heated during that period.

TABLE V.—*Total estimated production by grades from plat 1, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 4 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 4 are presented in Table VIII.]

Classification.	Date of picking.								Total for year.
	Feb. 14.	Apr. 7.	May 14.	June 24.	Aug. 11.	Sept. 12	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	0	13,300	2,500	2,160	540	300	1,100	9,280	29,180
Tree-Ripe grade	0	5,900	320	1,100	640	1,080	600	40	9,680
Total merchantable fruit	0	19,200	2,820	3,260	1,180	1,380	1,700	9,320	38,860
Cull grade	0	1,600	320	740	460	220	800	420	4,560
Frozen grade	183,140	83,360	5,580	1,100	60	340	0	0	273,580
Total	183,140	104,160	8,720	5,100	1,700	1,940	2,500	9,740	317,000
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	0 0	3,506 4	660 0	488 12	125 0	60 0	282 8	2,511 4	7,633 12
Tree-Ripe grade	0 0	1,268 12	73 12	207 8	111 4	145 0	87 8	10 0	1,903 12
Total merchantable fruit	0 0	4,775 0	733 12	696 4	236 4	205 0	370 0	2,521 4	9,537 8
Cull grade	0 0	275 0	60 0	91 4	51 4	28 12	80 0	65 0	651 4
Frozen grade	17,952 8	10,633 12	733 12	101 4	12 8	46 4	0 0	0 0	29,480 0
Total	17,952 8	15,683 12	1,527 8	888 12	300 0	280 0	450 0	2,586 4	39,668 12

A study of the figures shown in Table V shows that at the first picking, on February 14, immediately following the freeze, all of the fruits were frozen. In April the estimated number of sound fruits was 19,200, as compared with 83,360 frozen fruits. In May there were 2,820 sound lemons and 5,580 frozen ones. In June there were 3,260 merchantable fruits, while the frozen fruits had dropped to 1,100. In succeeding pickings the relative proportion of sound fruits to frozen ones is more marked, with a gradual increase in the

good fruits, until the December picking, when a total of 9,320 merchantable lemons is recorded, as compared with no frozen ones.

Table VI shows the estimated production by grades for an acre of Lisbon lemon trees (plat 2) during the calendar year 1913. These figures are calculated from the actual individual-tree performance records of five selected trees in the plat. This orchard was not heated during the winter of 1912–13, but was partially protected by heaters in neighboring orchards. It was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated during that period.

TABLE VI.—*Total estimated production by grades from plat 2, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was not heated during the winter of 1912-13 and was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated during that period. Plat 2 was partially protected by heaters in neighboring orchards. The data from plat 3 are presented in Table VII.]

Classification.	Date of picking.						Total for year.
	Feb. 15.	Apr. 4.	May 27.	June 24.	Aug. 20.	Nov. 17.	
Number of fruits:							
Green grade	16,700	33,160	15,700	6,880	10,480	3,480	86,400
Tree-Ripe grade	120	3,340	4,400	2,560	6,080	1,860	18,360
Total merchantable fruit.	16,820	36,500	20,100	9,440	16,560	5,340	104,760
Cull grade	0	780	1,660	1,300	680	2,220	6,640
Frozen grade	54,220	72,640	7,360	1,260	2,180	2,360	140,020
Total	71,040	109,920	29,120	12,000	19,420	9,920	251,420
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	4,235 0	8,621 4	4,081 4	1,742 8	2,251 4	961 4	21,892 8
Tree-Ripe grade	28 12	648 12	873 12	512 8	1,038 12	328 12	3,431 4
Total merchantable fruit.	4,263 12	9,270 0	4,955 0	2,255 0	3,290 0	1,290 0	25,323 12
Cull grade	0 0	108 12	240 0	143 12	93 12	333 12	920 0
Frozen grade	5,551 4	10,413 12	1,172 8	196 4	307 8	337 8	17,978 12
Total	9,815 0	19,792 8	6,367 8	2,595 0	3,691 4	1,961 4	44,222 8

A study of the figures in Table VI shows that a large percentage of the fruit in the February and April pickings was frozen. The small number of merchantable fruits recorded at the different pickings throughout the year in this plat is due to the fact that the trees were somewhat protected. This plat, like plat 1, had about returned to normal production at the close of the year.

In Tables VII to XIV, inclusive, the estimated production is shown by grades for plats 3 to 10, inclusive, as described in Table II.

TABLE VII.—*Total estimated production by grades from plat 3, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka lemon trees. This plat was not heated during the winter of 1912-13 and was selected for comparison with plat 2 in an orchard of Lisbon lemon trees which was not heated during that period and with plats 5 and 7 in orchards of Eureka lemon trees which were heated during that same period. Plat 3 was partially protected by heaters in neighboring orchards. The data from plat 2 are presented in Table VI, from plat 5 in Table IX, and from plat 7 in Table XI.]

Classification.	Date of picking.						Total for year.
	Feb. 15.	Apr. 5.	May 27.	June 24.	Aug. 20.	Nov. 17.	
Number of fruits:							
Green grade	10,330	6,630	1,620	390	1,330	4,750	25,050
Tree-Ripe grade	400	3,070	890	150	520	2,160	7,190
Total merchantable fruit	10,730	9,700	2,510	540	1,850	6,910	32,240
Cull grade	0	260	540	30	200	2,590	3,620
Frozen grade	99,510	29,880	2,190	630	1,550	2,620	136,380
Total	110,240	39,840	5,240	1,200	3,600	12,120	172,240
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	2,519 6	1,769 6	431 14	106 4	301 4	1,331 14	6,460 0
Tree-Ripe grade	91 4	682 8	200 10	29 6	85 10	376 4	1,465 10
Total merchantable fruit	2,610 10	2,451 14	632 8	135 10	386 14	1,708 2	7,925 10
Cull grade	0 0	41 14	115 0	5 10	22 8	293 12	478 12
Frozen grade	6,156 14	4,555 10	318 2	76 4	196 4	290 0	11,603 2
Total	8,767 8	7,059 6	1,065 10	217 8	605 10	2,291 14	20,007 8

TABLE VIII.—*Total estimated production by grades from plat 4, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of five Lisbon lemon trees. This plat was heated during the winter of 1912-13 and was selected for comparison with plat 1 in an orchard of Lisbon lemon trees, which was not heated during that period. The data from plat 1 are presented in Table V.]

Classification.	Date of picking.							Total for year.
	Mar. 3.	Apr. 1.	May 19.	June 23.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	52,620	9,420	17,980	8,300	2,740	1,080	1,520	11,360	105,020
Tree-Ripe grade	39,840	3,020	4,840	3,160	4,420	2,340	700	80	58,400
Total merchantable fruit	92,460	12,440	22,820	11,460	7,160	3,420	2,220	11,440	163,420
Cull grade	0	1,260	2,600	320	580	160	580	0	5,500
Frozen grade	28,960	1,980	1,320	280	40	40	0	0	32,620
Total	121,420	15,680	26,740	12,060	7,780	3,620	2,800	11,440	201,540
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	13,132 8	2,277 8	2,543 12	2,148 12	681 4	227 8	400 0	3,051 4	24,462 8
Tree-Ripe grade	7,848 12	542 8	982 8	666 4	863 12	373 12	102 8	20 0	11,400 0
Total merchantable fruit	20,981 4	2,820 0	3,526 4	2,815 0	1,545 0	601 4	502 8	3,071 4	35,862 8
Cull grade	0 0	143 12	361 4	47 8	70 0	18 12	50 0	0 0	691 4
Frozen grade	4,045 0	217 8	223 12	53 12	6 4	6 4	0 0	0 0	4,552 8
Total	25,026 4	3,181 4	4,111 4	2,916 4	1,621 4	626 4	552 8	3,071 4	41,106 4

TABLE IX.—*Total estimated production by grades from plat 5, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka trees. This plat was inadequately heated during the winter of 1912–13 and was selected for comparison with plat 3 in an orchard of Eureka lemon trees which was not heated and with plat 7 in an orchard of Eureka lemon trees which was adequately heated during that same period. The data from plat 7 are presented in Table XI and from plat 3 in Table VII.]

Classification.	Date of picking.								Total for year.
	Mar. 4.	Apr. 2.	May 20.	June 27.	Aug. 12.	Sept. 13.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	18,420	2,430	3,580	2,170	770	310	520	3,180	31,380
Tree-Ripe grade	31,420	4,250	2,560	2,810	1,260	710	2,300	110	45,420
Total merchantable fruit	49,840	6,680	6,140	4,980	2,030	1,020	2,820	3,290	76,800
Cull grade	0	1,070	2,580	310	520	140	2,360	160	7,140
Frozen grade	19,610	1,610	470	60	0	60	0	0	21,810
Total	69,450	9,360	9,190	5,350	2,550	1,220	5,180	3,450	105,750
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	4,856 4	570 10	898 12	496 14	185 0	65 10	119 6	828 12	8,021 4
Tree-Ripe grade	6,059 6	744 6	496 14	526 14	233 12	109 6	318 2	25 0	8,513 12
Total merchantable fruit	10,915 10	1,315 0	1,395 10	1,023 12	418 12	175 0	437 8	853 12	16,535 0
Cull grade	0 0	118 12	322 8	35 0	65 10	15 0	151 4	13 12	721 14
Frozen grade	2,565 10	187 8	74 6	6 14	0 0	6 14	0 0	0 0	2,841 4
Total	13,481 4	1,621 4	1,792 8	1,065 10	484 6	196 14	588 12	867 8	20,098 2

TABLE X.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 8 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 8 are presented in Table XII.]

Classification.	Date of picking.								Total for year.
	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.	
Number of fruits:									
Green grade	30,030	3,810	2,070	5,390	3,920	1,240	2,430	7,900	56,790
Tree-Ripe grade	10,270	390	200	740	540	950	2,320	2,610	18,020
Total merchantable fruit	40,300	4,200	2,270	6,130	4,460	2,190	4,750	10,510	64,810
Cull grade	0	430	220	200	550	510	700	610	3,220
Frozen grade	4,900	860	140	0	0	580	2,380	240	9,100
Total	45,200	5,490	2,630	6,330	5,010	3,280	7,830	11,360	87,130
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	8,516 4	1,024 6	581 4	1,475 0	986 4	288 2	591 14	2,111 14	15,575 0
Tree-Ripe grade	2,155 10	80 10	51 4	151 14	105 10	150 0	392 8	478 12	3,566 4
Total merchantable fruit	10,671 14	1,105 0	632 8	1,626 14	1,091 14	438 2	984 6	2,590 10	19,141 4
Cull grade	0 0	66 14	31 4	24 6	86 14	60 0	86 4	74 6	430 0
Frozen grade	831 4	98 2	26 4	0 0	0 0	60 10	283 2	33 12	1,333 2
Total	11,503 2	1,270 0	690 0	1,651 4	1,178 12	558 12	1,353 12	2,698 12	20,904 6

TABLE XI.—*Total estimated production by grades from plat 7, an acre of Eureka lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Eureka lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 5 in an orchard of Eureka lemon trees which was inadequately heated during the winter of 1912–13 and with plat 3 in an orchard of Eureka lemon trees which was not heated during that same period. The data from plat 5 are presented in Table IX and from plat 3 in Table VII.]

Classification.	Date of picking.							Total for year.
	Mar. 7.	Apr. 3.	May 21.	June 24.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.	
Number of fruits:									
Green grade	42,480	3,970	3,780	3,490	2,110	1,260	2,150	3,020	62,260
Tree-Ripe grade	48,540	3,800	2,250	3,270	3,650	2,620	4,870	1,320	70,320
Total merchantable fruit	91,020	7,770	6,030	6,760	5,760	3,880	7,020	4,340	132,580
Cull grade	0	1,080	2,580	430	650	300	4,480	600	10,120
Frozen grade	6,020	0	10	0	0	20	0	0	6,050
Total	97,040	8,850	8,620	7,190	6,410	4,200	11,500	4,940	148,750
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	11,528 12	995 0	990 0	919 6	500 0	263 2	515 10	820 10	16,532 8
Tree-Ripe grade	10,170 0	702 8	451 4	677 8	620 0	382 8	746 4	335 10	14,085 10
Total merchantable fruit	21,698 12	1,697 8	1,441 4	1,596 14	1,120 0	645 10	1,261 14	1,156 4	30,618 2
Cull grade	0 0	140 10	372 8	57 8	82 8	35 10	369 6	96 4	1,154 6
Frozen grade	841 4	0 0	1 4	0 0	0 0	2 8	0 0	0 0	845 0
Total	22,540 0	1,838 2	1,815 0	1,654 6	1,202 8	683 12	1,631 4	1,252 8	32,617 8

TABLE XII.—*Total estimated production, by grades, from plat 8, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 6 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 6 are presented in Table X.]

Classification.	Date of picking.			Total for year.
	Mar. 10.	Nov. 10.	Dec. 18.	
Number of fruits:				
Green grade	2,130	5,780	16,450	24,360
Tree-Ripe grade	1,570	30	70	1,670
Total merchantable fruit	3,700	5,810	16,520	26,030
Cull grade	0	120	170	290
Frozen grade	116,670	0	0	116,670
Total	120,370	5,930	16,690	142,990
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	477 8	1,538 2	4,417 8	6,433 2
Tree-Ripe grade	306 4	5 10	16 14	328 12
Total merchantable fruit	783 12	1,543 12	4,434 6	6,761 14
Cull grade	0 0	13 12	23 12	37 8
Frozen grade	13,685 10	0 0	0 0	13,685 10
Total	14,469 6	1,557 8	4,458 2	20,485 0

TABLE XIII.—*Total estimated production, by grades, from plat 9, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1912–13 and was selected for comparison with plat 10 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 10 are presented in Table XIV.]

Classification.	Date of picking.								Total for year.
	Mar. 12.	Apr. 3.	May 13.	June 25.	Aug. 12.	Sept. 13.	Oct. 25.	Dec. 12.	
Number of fruits:									
Green grade	64,440	10,270	23,080	19,580	4,900	2,950	220	3,320	128,760
Tree-Ripe grade	80,100	2,310	2,030	21,920	6,400	3,620	1,050	200	117,630
Total merchantable fruit	144,540	12,580	25,110	41,500	11,300	6,570	1,270	3,520	246,390
Cull grade	0	890	2,630	1,870	640	660	2,310	70	9,070
Frozen grade	8,380	60	10	40	0	0	0	0	8,490
Total	152,920	13,530	27,750	43,410	11,940	7,230	3,580	3,590	253,950
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	16,752 8	2,513 2	5,744 6	4,935 0	1,170 0	621 4	57 8	868 12	32,662 8
Tree-Ripe grade	15,280 10	440 0	449 6	4,303 12	1,246 14	575 10	157 8	50 10	22,504 6
Total merchantable fruit	32,033 2	2,953 2	6,193 12	9,238 12	2,416 14	1,196 14	215 0	919 6	55,166 14
Cull grade	0 0	120 10	412 8	222 8	93 2	84 6	120 0	10 0	1,063 2
Frozen grade	924 6	8 12	2 8	5 10	0 0	0 0	0 0	0 0	941 4
Total	32,957 8	3,082 8	6,608 12	9,466 14	2,510 0	1,281 4	335 0	929 6	57,171 4

TABLE XIV.—*Total estimated production, by grades, from plat 10, an acre of Lisbon lemon trees, for each picking during the calendar year 1913.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1912–13 and was selected for comparison with plat 9 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 9 are presented in Table XIII.]

Classification.	Date of picking.				Total for year.
	Mar. 12.	May 13.	June 26.	Dec. 1.	
Number of fruits:					
Green grade	3,470	160	450	3,090	7,170
Tree-Ripe grade	4,460	10	1,510	170	6,150
Total merchantable fruit	7,930	170	1,960	3,260	13,320
Cull grade	0	90	120	80	290
Frozen grade	155,230	0	40	0	155,270
Total	163,160	260	2,120	3,340	168,880
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	810 10	35 0	107 8	865 0	1,818 2
Tree-Ripe grade	782 8	1 14	251 14	27 8	1,063 12
Total merchantable fruit	1,593 2	36 14	359 6	892 8	2,881 14
Cull grade	0 0	13 12	11 14	9 6	35 0
Frozen grade	14,475 10	0 0	4 6	0 0	14,480 0
Total	16,068 12	50 10	375 10	901 14	17,396 14

In studying the figures presented in the accompanying tables it will be seen that in all the nonheated plats large numbers of frozen fruits were taken from the trees during the first six months following

the freeze. In some of the nonheated plats, very few merchantable fruits were taken from the trees during the same period. On the other hand, in the heated plats the greater proportion of the fruit, even during the period immediately following the freeze, was merchantable, with a relatively small number of frozen lemons.

In order to illustrate these comparisons graphically, some diagrams are presented. Figure 6 gives the proportion of frozen and merchantable fruits produced on plat 1, an acre of nonheated Lisbon lemon trees, and plat 4, an acre of heated Lisbon lemon trees, for each picking during the calendar year 1913. This diagram is based upon the data presented for these plats in Tables V and VIII.

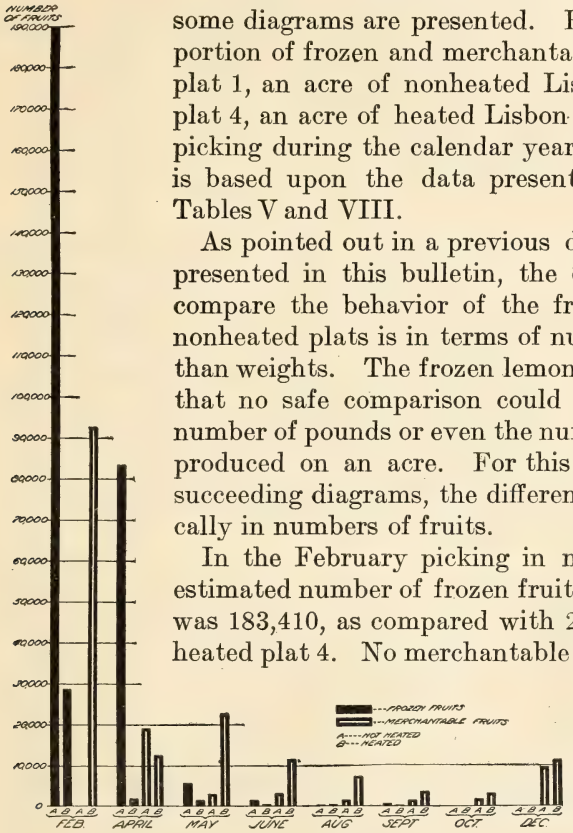


FIG. 6.—Diagram showing the number of frozen and merchantable fruits produced on plat 1, a nonheated acre of Lisbon lemon trees, and plat 4, an acre of heated Lisbon lemon trees. The figures here shown are taken from Tables V and VIII, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

As pointed out in a previous discussion of the data presented in this bulletin, the only accurate way to compare the behavior of the fruits in the heated and nonheated plats is in terms of numbers of fruits rather than weights. The frozen lemons dried out so rapidly that no safe comparison could be made by using the number of pounds or even the number of boxes of fruits produced on an acre. For this reason, in this and all succeeding diagrams, the differences are shown graphically in numbers of fruits.

In the February picking in nonheated plat 1, the estimated number of frozen fruits taken from the trees was 183,410, as compared with 28,960 frozen fruits in heated plat 4. No merchantable fruits were taken from the nonheated orchard at that picking, while 92,460 merchantable lemons were picked in the heated orchard during the same period. While many of the frozen fruits which were taken from the trees at that time normally would not have been picked until much later in the season, in order to obtain any records of these fruits it was necessary to pick all which showed signs of having been frozen. All fruits about which there was any question were left until later pickings. This condition applied to all the plats.

In the April picking the estimated number of frozen lemons removed from the nonheated plat was 83,360, as compared with 1,980 from

the heated plat. In the nonheated plat 19,200 merchantable fruits were taken from the trees, as compared with 12,440 merchantable fruits in the heated orchard.

In the May picking relatively few frozen fruits were taken from either plat, but only 2,820 merchantable lemons were found in the nonheated orchard, as compared with 22,820 in the heated one.

With the exception of the April picking, in which the first merchantable fruits were taken from the frozen plat, the heated plat produced a greater percentage of merchantable lemons during each picking throughout the calendar year until the last picking in December. At this time the trees in the frozen orchard had about returned to normal production.

A study of the tables and diagrams presented for the other plats shows that practically all the nonheated orchards had returned to normal production by the end of the calendar year.

A similar comparison is shown in figure 7, which portrays graphically the proportion of frozen and merchantable lemons produced on plat 9, an acre of heated Lisbon lemon trees, in comparison with plat 10, an acre of nonheated Lisbon lemon trees. Practically all the frozen fruits in the nonheated orchard were removed from the trees at the first picking in March. The heated orchard had 8,380 frozen fruits during that month, as compared with 144,540 merchantable lemons. During the succeeding months the heated orchard bore a considerable number of sound fruits, while no merchantable lemons were taken from the frozen plat until the December picking, when the trees had about returned to normal production.

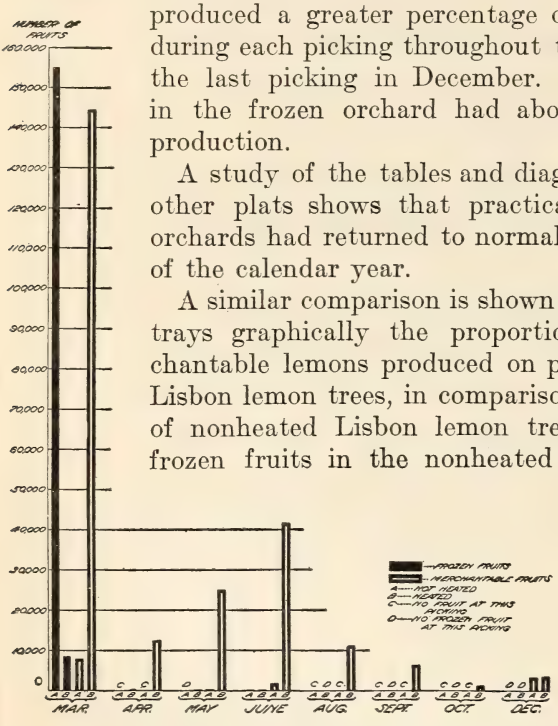


FIG. 7.—Diagram showing the number of frozen and merchantable fruits produced on plat 9, a heated acre of Lisbon lemon trees, and plat 10, a nonheated acre of Lisbon lemon trees. The figures here shown are taken from Tables XIII and XIV, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

Figure 8 shows the number of frozen and merchantable lemons produced on an acre of nonheated Eureka lemon trees (plat 3), as compared with an acre of partially heated (plat 5) and an acre of heated trees (plat 7).

As in figures 6 and 7, the greater proportion of the fruit in the nonheated orchard is found in the frozen column, with a smaller number in the partially heated orchard, and very few frozen fruits in the heated orchard. This diagram shows very clearly the beneficial

effect of even a small number of heaters in an orchard, but also presents strikingly the value of efficient heating in orchards, as the number of merchantable fruits produced during the year 1913 in the adequately heated orchard is much greater than that produced in the partially heated one.

Table XV shows the percentages of fruits by grades for each picking during the calendar year 1913 in the nonheated plat 1, an acre of Lisbon lemon trees, as compared with the heated plat 4. The percentages of frozen and merchantable fruits in these plats are shown graphically in figure 9. A study of this diagram shows that in the heated plat the percentage of merchantable lemons during February was 76, while in the nonheated plat the percentage of merchantable fruits was zero. At no time during the calendar year did the curve of merchantable fruits in the heated plat fall below the curve of the same class of fruits in the nonheated one. Correspondingly, the curve of the frozen lemons shows a relatively higher percentage during all the pickings up to October in the nonheated orchard, as compared with a low percentage of this class of fruits in the heated one.

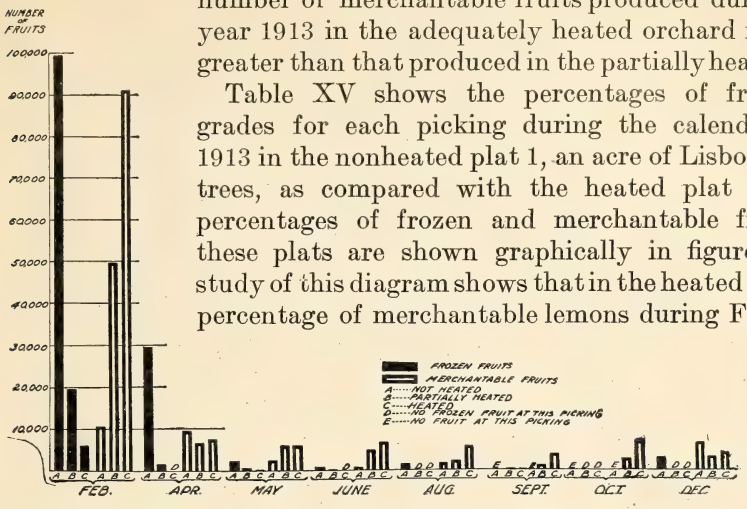


FIG. 8.—Diagram showing the number of frozen and merchantable fruits produced on plat 3, a nonheated acre of Eureka lemon trees, plat 5, a partially heated acre of Eureka lemon trees, and plat 7, an efficiently heated acre of Eureka lemon trees. The figures here shown are taken from Tables VII, IX, and XI, respectively, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

TABLE XV.—*Percentages of fruits by grades produced in the nonheated acre of Lisbon lemon trees, plat 1, as compared with the heated acre, plat 4, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats as shown in Tables V and VIII.]

Grade and condition.	Date of picking.							
	Feb. 14.	Apr. 7.	May 14.	June 24.	Aug. 11.	Sept. 12.	Oct. 26.	Dec. 12.
Green grade:								
Not heated	0	12.77	28.67	42.35	31.76	15.46	44.0	95.28
Heated	43.35	60.08	67.24	68.80	35.22	29.83	54.28	99.30
Tree-Ripe grade:								
Not heated	0	5.66	3.67	21.57	37.65	55.67	24.0	.41
Heated	32.81	19.26	18.10	26.20	56.81	64.64	25.0	.70
Merchantable fruit:								
Not heated	0	18.43	32.34	63.92	69.41	71.13	68.0	95.69
Heated	76.16	79.34	85.34	95.0	92.03	94.47	79.28	100
Cull grade:								
Not heated	0	1.54	3.67	14.57	27.06	11.34	32.0	4.31
Heated	0	8.03	9.72	2.65	7.45	4.42	20.72	0
Frozen grade:								
Not heated	100	80.04	63.99	21.57	3.56	17.53	0	0
Heated	23.84	12.63	4.94	2.35	.52	1.11	0	0

Table XVI gives the percentages of fruits by grades for each picking during the calendar year 1913 in the heated plat 6, an acre of Lisbon lemon trees, as compared with the nonheated plat 8. The percentages of frozen and merchantable fruits in these plats are shown graphically in figure 10.

Table XVII gives the percentages of fruits by grades for each picking during the calendar year 1913 in nonheated plat 3, an acre of Eureka lemon trees, as compared with plat 5, inadequately heated, and plat 7, efficiently heated. The percentages of frozen and merchantable fruits in these plats are shown in figure 11.

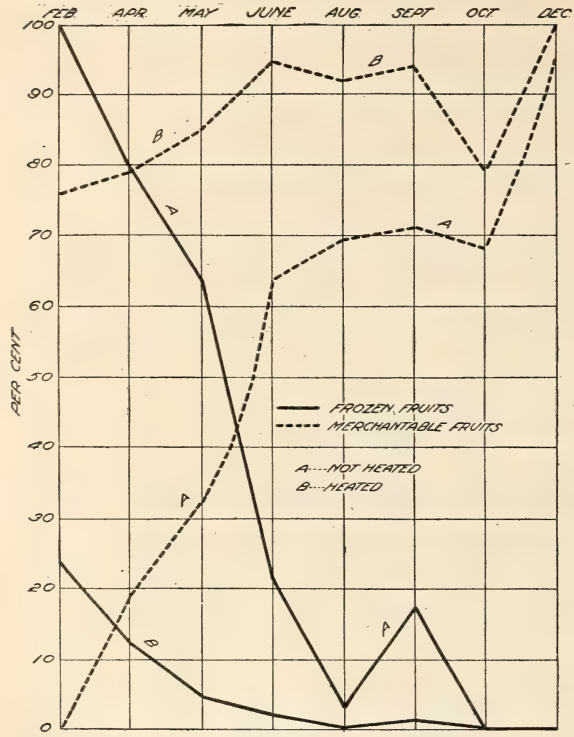


FIG. 9.—Diagram prepared from the figures presented in Table XV, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 1, as compared with the heated acre, plat 4, during the calendar year 1913.

TABLE XVI.—*Percentages of fruits by grades produced in the heated acre of Lisbon lemon trees, plat 6, as compared with the nonheated acre, plat 8, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats as shown in Tables X and XII.]

Grade and condition.	Date of picking.							
	Mar. 6.	Apr. 2.	May 14.	June 27.	Aug. 13.	Sept. 15.	Oct. 27.	Dec. 8.
Green grade:								
Not heated	1.77	(1)	(1)	(1)	(1)	(1)	97.47	98.56
Heated	66.44	69.40	78.71	85.15	78.24	37.80	31.03	69.54
Tree-Ripe grade:								
Not heated	1.30	(1)	(1)	(1)	(1)	(1)	.51	.41
Heated	22.72	7.10	7.60	11.69	10.78	28.96	29.73	22.97
Merchantable fruit:								
Not heated	3.07	(1)	(1)	(1)	(1)	(1)	97.98	98.97
Heated	89.16	76.50	86.31	96.84	89.02	66.76	60.76	92.51
Cull grade:								
Not heated	0	(1)	(1)	(1)	(1)	(1)	2.02	1.02
Heated	0	7.83	8.36	3.16	10.98	15.55	8.94	5.37
Frozen grade:								
Not heated	96.93	(1)	(1)	(1)	(1)	(1)	0	0
Heated	10.84	15.66	5.32	0	0	17.68	30.40	2.11

[1] Practically all the fruits in the nonheated plat were frozen and were removed from the trees on March 6. No fruits were picked from this plat until October.

TABLE XVII.—*Percentages of fruits by grades produced in the nonheated acre of Eureka lemon trees, plat 3, as compared with the inadequately heated plat 5, and the efficiently heated plat 7, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables VII, IX, and XI.]

Grade and condition.	Date of picking.							
	Mar. 4.	Apr. 2.	May 20.	June 24.	Aug. 12.	Sept. 13.	Oct. 26.	Dec. 12.
Green grade:								
Not heated	9.37	16.64	30.92	32.50	36.94	(1)	39.19	(1)
Partially heated	26.52	25.96	38.96	40.56	30.20	25.41	10.03	92.17
Heated	43.78	44.86	43.85	48.54	32.92	30.0	18.69	61.13
Tree-Ripe grade:								
Not heated	.36	7.71	16.98	12.50	14.44	(1)	17.82	(1)
Partially heated	45.24	45.40	27.86	52.52	49.41	58.20	44.44	3.19
Heated	50.02	42.94	26.10	45.48	56.94	62.38	42.35	26.73
Merchantable fruit:								
Not heated	9.73	24.35	47.90	45.0	51.38	(1)	57.01	(1)
Partially heated	71.76	71.36	66.82	93.08	79.61	83.61	54.47	95.36
Heated	93.80	87.80	69.95	94.02	89.86	92.38	61.04	87.86
Cull grade:								
Not heated	0	.65	10.31	2.50	5.56	(1)	21.37	(1)
Partially heated	0	11.43	28.07	5.79	20.39	11.47	45.56	4.64
Heated	0	12.20	29.93	5.98	10.14	7.14	38.96	12.14
Frozen grade:								
Not heated	90.27	75.0	41.79	52.50	43.05	(1)	21.62	(1)
Partially heated	28.24	17.20	5.11	1.12	0	4.92	0	0
Heated	6.20	0	.12	0	0	.48	0	0

[1] No pickings were made from the nonheated plat 3 in September or December.

A study of figure 11 shows that with one exception the curves of merchantable fruit in both the inadequately heated and the efficiently heated plats are considerably higher than the curve of the same class of fruit in the nonheated orchard. The diagram also presents strikingly the differences in percentages of merchantable fruits in the partially heated and efficiently heated orchards. With the exception of the picking in December, the percentages of merchantable fruit in the partially heated orchard are found to be somewhat lower than the same class of fruit in the well-heated one.

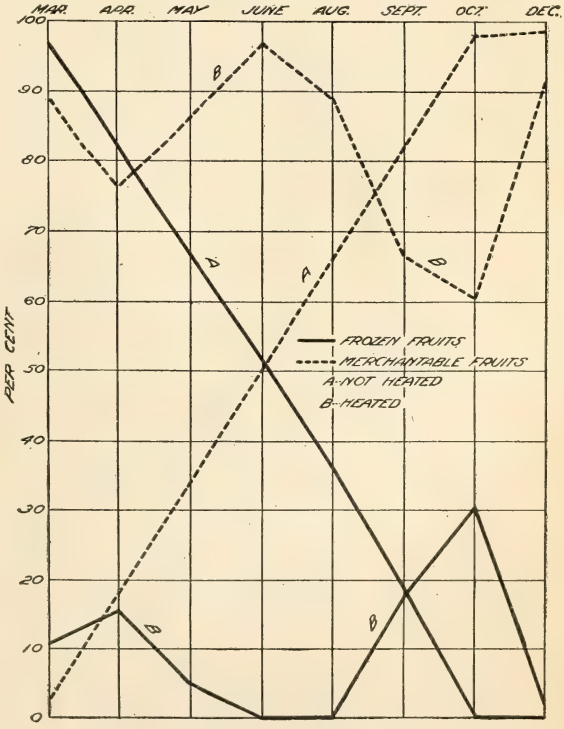


FIG. 10.—Diagram prepared from the figures presented in Table XVI, showing the percentages of merchantable and frozen fruits produced on the heated acre of Lisbon lemon trees, plat 6, as compared with the nonheated acre, plat 8, during the calendar year 1913.

TABLE XVIII.—*Percentages of fruits by grades produced in the nonheated acre of Lisbon lemon trees, plat 10, as compared with the heated plat 9, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables XIII and XIV.]

Grade and condition.	Date of picking.							
	Mar. 12.	Apr. 3.	May 13.	June 25.	Aug. 12.	Sept. 13.	Oct. 25.	Dec. 12.
Green grade:								
Not heated	2.13	(1)	61.54	21.23	(1)	(1)	(1)	92.51
Heated	42.14	75.91	83.17	45.11	41.04	40.80	6.15	92.48
Tree-Ripe grade:								
Not heated	2.73	(1)	3.85	71.23	(1)	(1)	(1)	5.09
Heated	52.38	17.07	7.32	50.50	53.61	50.07	29.33	5.57
Merchantable fruit:								
Not heated	4.86	(1)	65.39	92.46	(1)	(1)	(1)	97.60
Heated	94.52	92.98	90.49	95.61	94.65	90.87	35.48	98.05
Cull grade:								
Not heated	0	(1)	34.61	5.66	(1)	(1)	(1)	2.40
Heated	0	6.58	9.48	4.31	5.36	9.13	64.53	1.95
Frozen grade:								
Not heated	95.14	(1)	0	1.89	(1)	(1)	(1)	0
Heated	5.48	.44	.04	.09	0	0	0	0

[1] The bulk of the fruits in the nonheated plat were frozen and were removed at the March picking. No fruits were taken from the trees during April, August, and September.

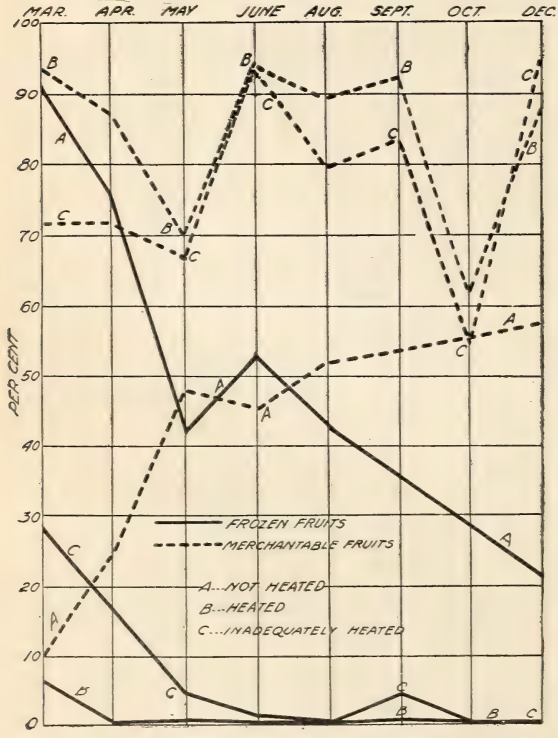


FIG. 11.—Diagram prepared from the figures presented in Table XVII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Eureka lemon trees, plat 3, as compared with the inadequately heated acre, plat 5, and the efficiently heated acre, plat 7, during the calendar year 1913.

Table XVIII gives the percentages of fruits by grades for each picking during the calendar year 1913 in the nonheated plat 10, an acre of Lisbon lemon trees, as compared with plat 9, an acre of heated trees. The percentages of frozen and merchantable fruits in these plats are shown in figure 12.

LESSONS TAUGHT BY THE INVESTIGATIONS IN 1913.

The data presented in this bulletin show that in the lemon orchards under investigation in the Corona district of California which were protected with a sufficient number of heaters during the freeze of

1913, a large percentage of merchantable fruits was saved and harvested during the various pickings throughout the year. The studies also show that in orchards which were not heated the number of merchantable fruits was relatively small; that a small proportion of the lemons picked during the first six months was frozen or unmerchantable, and that the trees did not return to normal production for about a year. From the data herewith presented it would appear that in sections where low temperatures are liable to be experienced lemon growers should see that their groves are equipped with some efficient means of orchard heating.

Table XIX presents a statement of the initial investment for heating equipment per acre and the cost of maintenance and operation for the season of 1912–13. On the particular ranch where these figures apply 186 acres were heated. Some of the heated plats considered in this bulletin were located on this ranch.

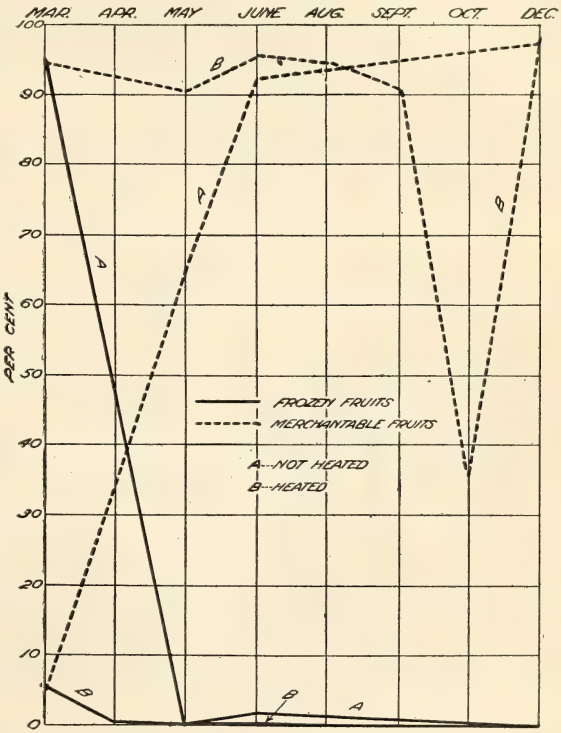


FIG. 12.—Diagram prepared from the figures presented in Table XVIII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 10, as compared with the heated acre, plat 9. during the calendar year 1913.

As the price received by the grower for merchantable lemons following a freeze is generally considerably higher than that received in normal years, unless he is able to save his crop by orchard heating he is not in a position to reap the benefit of the higher prices which would be obtained during the season of scarcity of sound fruit, and in addition he faces the possibility of losing the greater percentage of his crop. If seasons of low temperature were experienced only at intervals of 10 or 15 years it is possible that growers in especially protected localities might consider that the losing of one year's crop would not be offset by the initial investment for heating equipment and cost of maintenance, which in 1913 was placed in the Corona

district at $190.04 per acre. The initial expense of the heating equipment and the cost of maintenance would be much greater at the present time (1920) than in 1913. However, the minimum temperatures experienced in California lemon sections during the last few years show that there is an ever-present danger of frost injury to lemon orchards unless they are safeguarded by an efficient system of heating. From the data presented in this bulletin and from cooperative information secured from lemon growers in different sections, it would appear that the installation of an orchard-heating equipment would be justified not in the saving of one season's crop but because of the frequency with which seasons of low temperatures occur.

TABLE XIX.—*Initial investment for heating equipment and expense per acre for the season of 1912–13 on a ranch of 186 acres at Corona, Calif., on which some of the investigational heated plats were located.*

Itemization.	Per acre.	
	By items.	Total.
Initial investment:		
Heaters	$50.17	
Oil tank	7.07	
Pipe for oil distribution system	17.49	$83.12
Miscellaneous equipment and supplies	7.50	
Labor, installing tank, pipe line, etc	3.89	
Cost of maintenance and operation for the season of 1912–13:		
6 per cent interest on investment	5.17	
25 per cent depreciation on heaters	12.54	
6 per cent depreciation on other equipment	2.16	103.92
Handling, painting, and filling heaters (estimated)	5.00	
Oil consumed	57.96	
Labor in lighting and refilling heaters	21.09	
Grand total (if charged to any one year)		190.04

TABLE XX.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1914.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was heated during the winter of 1913 and was selected for comparison with plat 8 in an orchard of Lisbon lemon trees which was not heated during that period. The data from plat 8 for the calendar year 1914 are shown in Table XXI.]

Classification.	Date of picking.					
	Jan. 3.	Feb. 14.	Mar. 23.	May 4.	June 3.	July 15.
Number of fruits:						
Green grade	30,260	52,120	32,580	22,380	8,640	5,930
Tree-Ripe grade	730	7,210	2,210	5,090	2,360	1,790
Total merchantable fruit	30,990	59,330	34,790	27,470	11,000	7,720
Cull grade	320	1,270	1,660	1,290	340	960
Total	31,310	60,600	36,450	28,760	11,340	8,680
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	7,782 8	14,098 2	8,999 6	5,993 12	2,220 0	1,440 0
Tree-Ripe grade	174 6	1,841 14	536 14	1,206 4	545 0	379 6
Total merchantable fruit	7,956 14	15,940 0	9,536 4	7,200 0	2,765 0	1,819 6
Cull grade	48 12	201 4	267 8	205 10	62 8	158 12
Total	8,005 10	16,141 4	9,803 12	7,405 10	2,827 8	1,978 2

TABLE XX.—*Total estimated production by grades from plat 6, an acre of Lisbon lemon trees, for each picking during the calendar year 1914*—Continued.

Classification.	Date of picking.					Total for year.
	Aug. 18.	Sept. 22.	Oct. 26.	Nov. 13.	Dec. 23.	
Number of fruits:						
Green grade	1,540	1,020	7,660	6,480	10,180	178,790
Tree-Ripe grade	840	1,600	350	490	1,480	24,150
Total merchantable fruit	2,380	2,620	8,010	6,970	11,660	202,940
Cull grade	1,610	450	200	130	240	8,470
Total	3,990	3,070	8,210	7,100	11,900	211,410
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	348 2	244 6	1,991 4	1,770 10	2,823 12	47,711 14
Tree-Ripe grade	154 6	295 10	65 10	96 14	378 2	5,674 6
Total merchantable fruit	502 8	540 0	2,056 14	1,867 8	3,201 14	53,386 4
Cull grade	256 14	62 8	33 2	20 0	35 10	1,352 8
Total	759 6	602 8	2,090 0	1,887 8	3,237 8	54,738 12

THE BEHAVIOR OF HEATED AND NONHEATED PLATS IN 1914.

Although practically all the nonheated plats had returned to normal production by January, 1914, in order to collect data on the behavior of trees in the year following the freeze it was decided to continue the individual-tree records in plat 6, a heated acre of Lisbon lemon trees, and in plat 8, which had not been protected in 1913. The production by grades in these plats during the calendar year 1914 is shown in Tables XX and XXI.

TABLE XXI.—*Total estimated production by grades from plat 8, an acre of Lisbon lemon trees, for each picking during the calendar year 1914.*

[The data in this plat were computed from the individual-tree records of ten Lisbon lemon trees. This plat was not heated during the winter of 1913 and was selected for comparison with plat 6 in an orchard of Lisbon lemon trees which was heated during that period. The data from plat 6 for the calendar year 1914 are shown in Table XX.]

Classification.	Date of picking.								Total for year.
	Jan. 31.	Mar. 14.	Apr. 21	June 3.	July 9.	Aug. 31.	Oct. 31.	Dec. 30.	
Number of fruits:									
Green grade	45,310	40,750	25,140	7,230	7,340	9,400	3,040	13,470	151,680
Tree-Ripe grade	1,490	2,540	11,950	1,090	510	920	2,170	4,380	25,050
Total merchantable fruit	46,800	43,290	37,090	8,320	7,850	10,320	5,210	17,850	176,730
Cull grade	150	1,350	1,210	400	510	760	300	270	4,950
Total	46,950	44,640	38,300	8,720	8,360	11,080	5,510	18,120	181,680
Weight of fruits:	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*	*Lbs. oz.*
Green grade	12,140 10	11,160 0	6,525 0	1,983 2	1,836 4	2,292 8	803 12	3,601 14	40,343 2
Tree-Ripe grade	358 12	640 10	2,324 6	233 2	97 8	191 4	502 8	1,143 12	5,491 14
Total merchantable fruit	12,499 6	11,800 10	8,849 6	2,216 4	1,933 12	2,483 12	1,306 4	4,745 10	45,835 0
Cull grade	29 6	178 12	197 8	60 0	71 14	139 6	53 12	58 12	789 6
Total	12,528 12	11,979 6	9,046 14	2,276 4	2,005 10	2,623 2	1,360 0	4,804 6	46,624 6

In figure 13 a graphic presentation of the yields of Lisbon lemon trees in the heated plat 6 and the nonheated plat 8 for the two years 1913 and 1914 is given. In 1913 the behavior of the nonheated plat was very similar to other nonheated plats in that the bulk of the fruits was frozen and was removed at the first picking. The plat did not return to normal production until December of that year. In January, 1914, the estimated number of merchantable fruits picked from the nonheated plat was 46,800, as compared with 30,990 on the heated one.

In referring to Tables XX and XXI it will be seen that 11 pickings were made in plat 6 during the calendar year 1914, as compared with 8 pickings in plat 8. This was due to the fact that the two orchards belonged to different companies, and a different system of picking was followed in each orchard. In order to make the data in figure 13 comparable, it was necessary to add the figures obtained in February and March in plat 6 and present them in comparison with the picking in plat 8 in March. The August and

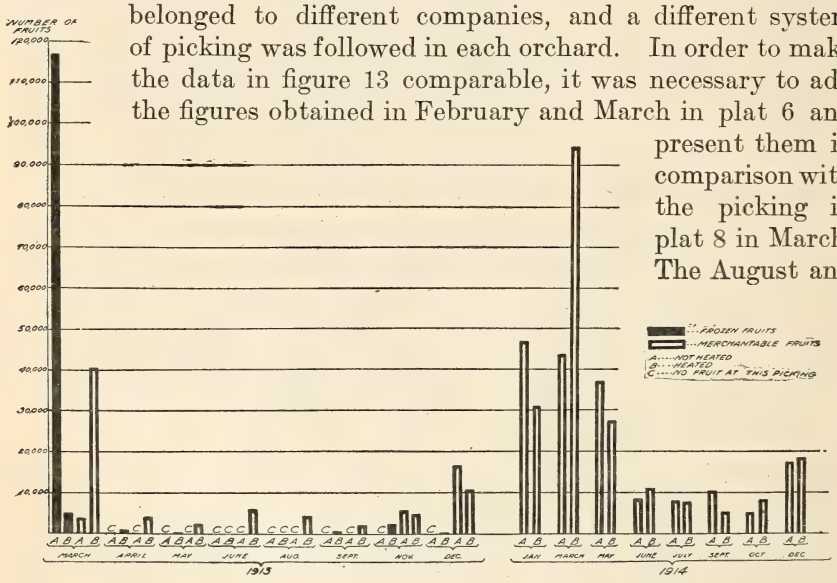


FIG. 13.—Diagram showing the number of frozen and merchantable fruits produced on plat 6, a heated acre of Lisbon lemon trees, and plat 8, a nonheated acre of Lisbon lemon trees, for the calendar years 1913 and 1914. The figures here shown are taken from Tables X, XII, XX, and XXI, respectively, which give the estimated production by grades for each month's picking for these plats during these years.

September pickings in plat 6 were totaled to make them comparable with the one picking made for the same period in plat 8. A similar addition was made of the September and October pickings in plat 6 to make them comparable with the fruit obtained in plat 8 for the same period. In March the fruits obtained from the heated plat were considerably more than those obtained from the nonheated plat. In May, however, the nonheated plat led, and after that month the two plats alternated throughout the year.

From the data secured in these two plats it would appear that the nonheated trees had returned to normal production by the beginning of 1914 and that the heating during the cold period in January, 1913, had practically no effect on the second season's crop. It must be

borne in mind, however, that the trees in this particular orchard were in a very vigorous and healthy condition at the time of the freeze, and with the exception of lack of heating had always received excellent care, which probably accounts for their rapid return to normal production. If the orchard had not received as good care or had the trees been in a less healthy growing condition, it is possible that they might not have returned to normal production so soon.

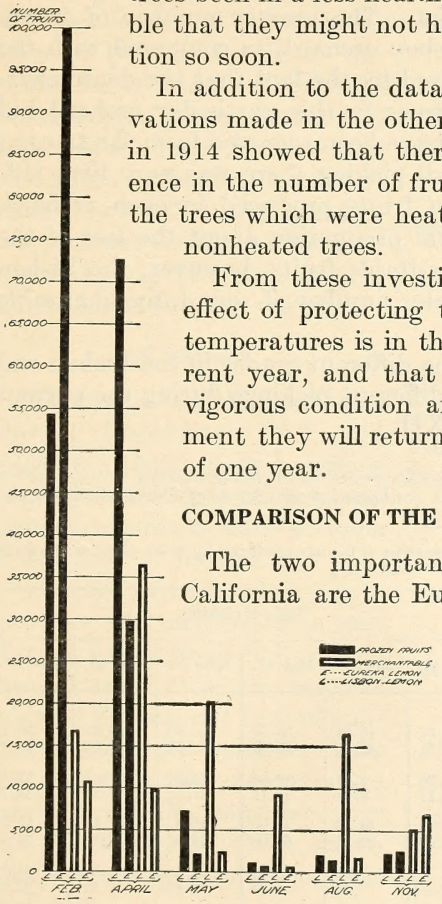


FIG. 14.—Diagram showing the number of frozen and merchantable fruits produced on plat 2, a nonheated acre of Lisbon lemon trees, and plat 3, a nonheated acre of Eureka lemon trees. The figures here shown are taken from Tables VI and VII, which give the estimated production by grades for each month's picking for these plats during the calendar year 1913.

In addition to the data covering these two plats, observations made in the other nonheated and heated orchards in 1914 showed that there was very little relative difference in the number of fruits produced the second year by the trees which were heated in 1913 as compared to the nonheated trees.

From these investigations it appears that the main effect of protecting trees during one season of low temperatures is in the saving of the crop for the current year, and that as a rule where the trees are in vigorous condition and receive good cultural treatment they will return to normal production at the end of one year.

COMPARISON OF THE EUREKA AND LISBON VARIETIES.

The two important varieties of lemons grown in California are the Eureka and the Lisbon. In order to secure some definite information as to the behavior of comparative plats in nonheated orchards, two blocks of trees, plats 2 and 3, were located, respectively, in Lisbon and Eureka lemon orchards. Both orchards were operated by the same man, the two plats under observation were only a short distance apart at practically the same altitude, and, as far as could be determined, the conditions were as nearly uniform in each orchard as it was possible to obtain. Both the orchards received some benefit from heaters in neighboring protected groves. A record of the production by grades during the calendar year 1913 for the nonheated Lisbon orchard is given in Table VI and for the nonheated Eureka orchard in Table VII. In figure 14 the number of frozen and merchantable fruits produced on each of these plats for the calendar year 1913 is given.

In February the estimated number of frozen fruits picked in the Lisbon plat was 54,220, as compared with 99,510 in the Eureka orchard. On account of the open habit of growth of the Eureka tree a larger number of mature or nearly mature lemons were frozen in this variety than in the Lisbon. In the April picking, however, the estimated number of frozen fruits in the Lisbon plat was 72,640, as compared with 29,880 in the Eureka. The greater number of frozen lemons at this picking in the Lisbon orchard, as compared with the preceding one, was probably caused by the fact that the dense character of growth of the Lisbon trees in this particular orchard hid many of the fruits which should have been removed from the trees at the first picking. After the April picking there was very little difference in the number of frozen fruits produced in each orchard. Both orchards returned to normal production about the last of the year. In the case of the merchantable fruits, however, the Lisbon plat at each picking bore a greater number of sound, merchantable lemons than the Eureka.

The percentages of fruits by the different grades in the Lisbon and Eureka nonheated plats for the different pickings during the current year 1913 are shown in Table XXII.

TABLE XXII.—*Percentages of fruits by grades produced on the nonheated acre of Lisbon lemon trees, plat 2, as compared with the nonheated acre, plat 3, of Eureka lemon trees, during the calendar year 1913.*

[These percentages are computed from the total number of lemons produced by these plats, as shown in Tables VI and VII.]

Grade and variety.	Date of picking.					
	Feb. 15.	Apr. 5.	May 27.	June 24.	Aug. 20.	Nov. 17.
Green grade:						
Eureka	9.37	16.64	30.92	32.50	36.94	39.19
Lisbon	23.51	30.17	53.91	57.33	53.96	35.09
Tree-Ripe grade:						
Eureka	.36	7.71	16.98	12.50	14.44	17.82
Lisbon	.17	3.04	15.11	21.33	31.31	18.75
Merchantable fruit:						
Eureka	9.73	24.35	47.90	45.0	51.38	57.01
Lisbon	23.68	33.21	69.02	78.66	85.27	53.84
Cull grade:						
Eureka	0	.65	10.31	2.50	5.56	21.37
Lisbon	0	.71	5.71	10.83	3.50	22.38
Frozen grade:						
Eureka	90.27	75.0	41.79	52.50	43.05	21.62
Lisbon	76.32	66.08	25.27	10.50	11.23	23.79

A graphic presentation of the percentages of frozen and merchantable fruits in the Eureka and Lisbon nonheated plats is made in figure 15. The percentage of frozen lemons at each picking in the Eureka plat is somewhat higher than the percentage of frozen ones in the Lisbon plat until the last pickings in November, when the percentages are nearly uniform. Correspondingly, the percentage of merchantable fruits at each picking is somewhat higher in the Lisbon block than in the other.

From the data secured in these plats and from observations made in other orchards it appears that the Lisbon variety, probably owing to its dense foliage and more compact habit of growth, was not quite so susceptible to frost injury as the Eureka. These observations apply entirely to groves which are not protected by orchard heaters. In well-protected orchards there were comparatively small numbers of frozen lemons of either the Eureka or Lisbon variety. It therefore appears that, although in unprotected orchards under similar conditions, a greater amount of injury is found in Eureka than in Lisbon orchards, the difference is not sufficiently great to warrant any positive statements concerning the comparative hardiness of the two varieties.

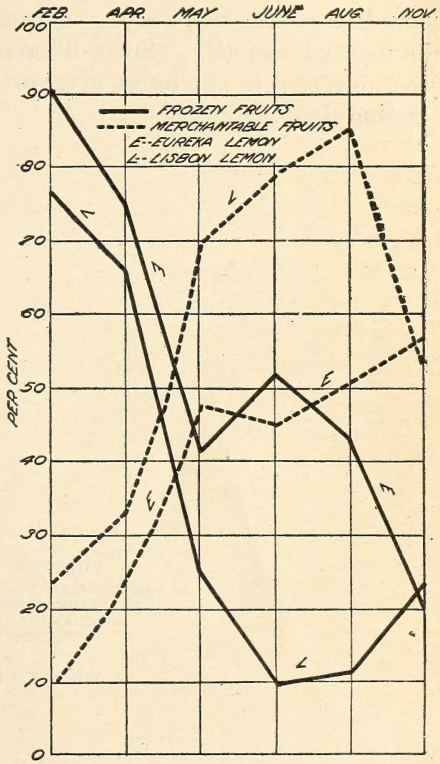


FIG. 15.—Diagram prepared from the figures presented in Table XXII, showing the percentages of merchantable and frozen fruits produced on the nonheated acre of Lisbon lemon trees, plat 2, as compared with the nonheated acre of Eureka lemon trees, plat 3, during the calendar year 1913.

SUMMARY.

Extremely low temperatures during December, 1912, and January, 1913, caused serious damage and loss to unprotected lemon orchards in many sections of southern California.

Detailed records of the proportion of merchantable and frozen fruits produced in five heated and five nonheated acre plats of Eureka and Lisbon lemons during the calendar year 1913 and in two comparative plats during the calendar year 1914 in the Corona, Calif., lemon district are presented in this bulletin.

These data show that in orchards which were protected with an adequate supply of heaters during the cold weather of 1912–13 a large percentage of merchantable fruit was saved and harvested throughout the year.

In orchards which were not heated a large proportion of the lemons picked during the first six months following the freeze were frozen or unmerchantable, and the trees did not return to normal production until a year had elapsed.

Nonheated orchards which had received good care prior to the freeze of 1913 and also during that year had returned to normal production by the beginning of 1914, and the heating during the cold period in 1913 had practically no effect on the second season's crop.

In unprotected orchards, under comparative conditions, a greater amount of injury was found in the Eureka than in the Lisbon variety. The differences were not sufficiently great, however, to warrant the conclusion that there is any considerable difference in the hardiness of the two varieties. Such differences as appeared were entirely due to differences in the habit of growth of the two varieties, the Lisbon having denser foliage.

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